BIOLOGY.—*Biological relationships of the mathematical series 1, 2, 4, etc., with a description of a new nema,* Tylenchus cancellatus, (Contributions to a Science of Nematology XV). N. A. COBB, U. S. Department of Agriculture.

The behavior of the components of matter, e.g., in chemical reactions, appears to compel discontinuous variation in the evolution of organisms. Organic evolution has been thought continuous, but mutation now suggests that it is discontinuous. Must it not necessarily be discontinuous[1] from the very nature of the composition of matter? Morphological changes in organisms originate in chemical changes in the *matter* of which they are composed. Now, a chemical change is one that either takes place or does not take place; nothing intermediate is known. Hence it seems that the fundamental changes in the evolution of organisms, so far as we can conceive at present, i.e., chemical changes, *must be saltatory.* But we cannot conceive of the greater and obvious (visible) changes, except as summations of these minute changes. The visible changes then must *per force* be considered of the same character as that of their components, i.e., all visible evolutionary changes in organisms *must be* of a saltatory nature.

The mathematics of the morphology of organic evolution may therefore be considered as, at least mainly, discontinuous,—arithmetical.

The material basis of life is discontinuous, but is the only known form of matter so organized as to grow and multiply by assimilation; in this lies the fundamental difference between living objects and all others;—not a mathematical difference.

Matter is dual, or less abstractly, there exists in matter an exceedingly widespread, probably universal, "bipolarity", exemplified, therefore, in organisms. The universality of "bipolarity" is more or less understood and generally admitted. Its universality might be assumed to prove, and at least very strongly suggests, its necessity. Assuming its necessity, this bipolarity determines that *cells, as well as many of their components,* multiplying, do so by binary division in a bipolar manner.[2]

[1] *Mathematics.* Arithmetic and its derivatives arose through everyday problems connected with matter, which is *discontinuous.* The Calculus, mathematics of continuity, arose through problems like those of astronomy, where the *continuity* of space and time impress us most vividly.

Quantity. It may be said we cannot conceive of anything so small that it cannot be divided, or so large that nothing can be added to it; but as the two opposite statements seem just as true, we find ourselves within two limits at each of which we confront something that must be so, but can't be so. Between these two irrationalities lie quantities we can handle rationally by mathematics.

[2] Thence "fore-and-aftness" and bilateral symmetry in organisms arose (doubtless modified by gravity). Bilateral symmetry seems the invariable result of the growth of what we may call, for lack of a better term, "untrammeled protoplasm." When protoplasm is "hampered," say by inorganic materials tending to produce other forms of symmetry—as, for instance, through the laws of crystallization—then bilaterality may be more or less masked; otherwise it is manifest. We readily recognize it in nearly all animals and plants.

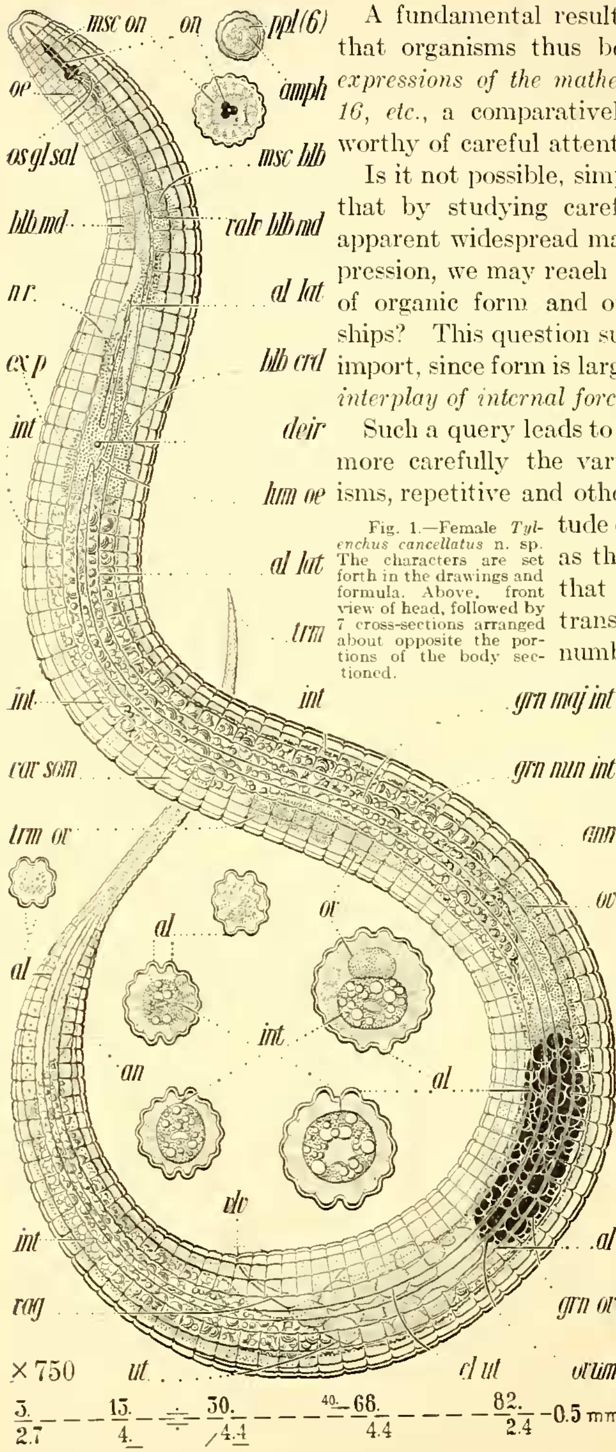

Fig. 1.—Female *Tylenchus cancellatus* n. sp. The characters are set forth in the drawings and formula. Above, front view of head, followed by 7 cross-sections arranged about opposite the portions of the body sectioned.

A fundamental result of this phenomenon is that organisms thus become *exact* or *modified expressions of the mathematical series 1, 2, 4, 8, 16, etc.*, a comparatively unheeded basic fact worthy of careful attention.

Is it not possible, simply by way of instance, that by studying carefully this more or less apparent widespread mathematico-biological expression, we may reach a clearer understanding of organic form and of phylogenetic relationships? This question suggests others of deeper import, since form is largely an expression of the *interplay of internal forces*.

Such a query leads to counting and comparing more carefully the various features of organisms, repetitive and otherwise. Among a multitude of others, such questions as this then arise: Why is it that both the number of transverse annules and the number of longitudinal elements in the cuticle of many nemas is likely to suggest some definite relationship to the geometrical series 1, 2, 4, 8, 16, etc.? The observed numbers are certainly cellular expressions of the 1, 2, 4 series, or variants, but why and according to what law is it that very often the numbers of elements met with are not members of the series but integers lying between? Why is it that chromosome-counts are suggestive of this same mathematical concept? And so on throughout the range of organic structures. Are not these numbers not only necessarily and definitely, but perhaps somewhat simply, modified mathematical expressions of the fundamental mathematico-biological phenomena inevitably arising from the fact that cells (as well as some of their components) divide in accordance with the 1, 2, 4 series?

Variations of the 1, 2, 4 series, as expressed in cell multiplication, say in a segmenting egg, can be readily diagrammed. (See Fig. 3.) If in such a cell-division diagram any particular multiplying cell or cells be pictured as halted, while the others continue to divide, the next step will bring about a variation from the geometrical series. If the reader will draw a few simple diagrams, he will find it easy, by such variations, graphically to represent, as existing at successive early stages in the imagined ontogeny, numbers of cells, say, from 1 to 10 inclusive, and will see that conceivably this could go on indefinitely, and that therefore *any number whatever* is a possible biological variation of the 1, 2, 4 series. But this broadening of the possibilities must not be allowed to obscure the basic fact that the *numbers are nevertheless definite mathematical variations of the 1, 2, 4 series due to the binary division of cells and their components;*—which in turn seems compulsory owing to the nature of matter itself. Our problem seems to be: Which of these numerous variations are the more significant, and what are their *mathematical and biological relationships?*

A new triplonch, *Tylenchus cancellatus* n. sp. (Figs. 1 and 2), infesting the roots of peonies, will serve, in a very limited way, to illustrate the foregoing remarks. The figures (Fig. 1) show the existence, near the head, of sixteen external longitudinal grooves. Near the middle of the neck this number changes to eighteen by the splitting, on each side of the nema, of one of the lateral, or sublateral, elements of the series, so that most of the body presents 18 grooves. Posteriorly this number reduces to 14, 10, then 8. (Fig. 1.)

This emphasizes the value of pondering the *variants* of the 1, 2, 4 series. If the numbers of the various elements were confined to the 1, 2, 4 series, they would be less significant, hence less useful;—e.g., in the interpretation of relationships. But variations abound, and are, as yet, for the most part unexplained; probably often highly complex. It is certain, however, that *if these variations can be envisaged and understood,* they will serve as basic data.

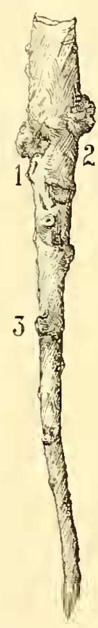

Fig. 2. Peony root (*Paeonia officinalis*), nat. size; swellings (1, 2, and 3) contain *Tylenchus cancellatus.*

There seems at present no way of stating exactly, the upper limit of the numbers representing these variations of the 1, 2, 4 series as exemplified in an organism. It may in some organisms reach twenty figures, and therefore the discovery and interpretation of some of the highest members of this modified geometrical series, as exemplified in organisms, may be beyond our present compass. Nevertheless, does it not seem likely that relationships traced in this manner may at least be set upon a *firmer basis* than is the case when data of other sorts are used,—or even upon an *entirely new basis?*

In a 1, 2, 4 series, let P_N be the final product and N its series number, then $P_N = 2^{N-1}$; thus, $16 = 2^{5-1}$.

Similarly in a simple organism, at any particular instant in its growth, let P_N have a corresponding value,—that is to say, be the number of cells that either actually exist or *would have arisen by the uniform and continuous* dichotomous division of the single primal cell. Such simple and easily understood organisms occur among the lower forms, and in the early embryonic stages of the higher forms, but are rare among the adult stages of the higher forms, because in these latter some cells lag or cease in their dichotomy, and because of losses of cells from various causes. Hence, the number of cells actually present in an organism at any particular instant is likely to be *P_N minus a certain number of cells,* (X), due to delay or failure in some part or parts of the dichotomy, or to loss. In this discussion account is taken of *all* the cells that have been produced during the growth, whether present in the organism at the proposed instant or not. This is in order to allow for worn out or wasted cells; these, possibly vanished, cells are *included in P_N.*

The general 1, 2, 4 equation of an organism thus becomes $P_N = 2^{N-1} - X$,

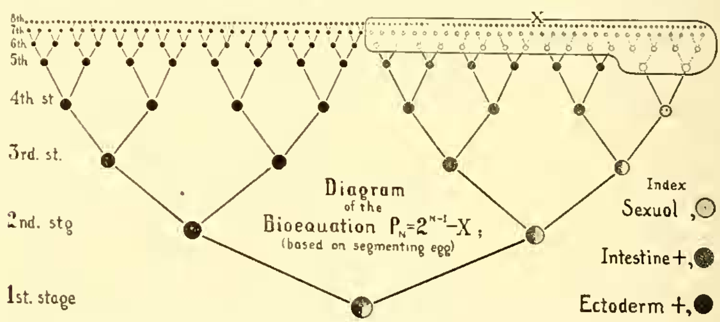

Fig. 3.—Diagram of 8 generations of cells produced by dichotomous divisions;—as, for instance, in a segmenting egg. Three general characters of tissue are shown: (1) Sexual, (2) intestinal and related tissues, (3) ectoderm and related tissues. The sexual and intestinal tissues are shown to have lagged behind those of the ectoderm, so that P_N in this instance equals 71.

in which *X is a whole number and a function of one or more "p's" of a lower* order, i.e., of the 1, 2, 4 character, or $p = 2^{n-1}$ character, in which, of course p is smaller than P and n is smaller than N. These smaller (ascertainable) groups are 1, 2, 4 groups of cells due to the lag or failure of *"earlier" generations than N.* (See the loop (X) in Fig. 3.)

$P_N = 2^{N-1} - X$ is a general equation, which, when $X = 0$, represents a strictly uniform and continuous mathematical dichotomy, found only in the lower organisms or in the early embryonic stages of the higher ones.

The various "p's" from P_N down to $P = 1$, (the primal number) become, therefore, *historical insignia, indicating particular generations of cells,* and may be made the basis of a *definite and fundamental mathematico-biological nomenclature* applicable to the generations of cells in an organism, and hence *to the organism itself.* Applications of the equation are endless.